Research Paper | Medical Science | E-ISSN No : 2454-9916 | Volume : 3 | Issue : 8 | Aug 2017

NANODENTISTRY

Dr. Rizwan Sanadi [1] | Dr. Meenu .V. Pillai [2]

[1] Professor, Department of Periodontics, Y. M. T Dental College and Hospital, Dr. G. D. Pol Foundation's YMT Dental College, Sector-4, Kharghar, Navi Mumbai-410210.

[2] PG Student 2nd Year, Department of Periodontics, Y.M.T Dental College and Hospital, Dr. G. D. Pol Foundation's YMT Dental College, Sector-4, Kharghar, NaviMumbai-410210.

ABSTRACT

In the current era of 21st century, it has become imperative to invent newer techniques in the field of dental diagnosis and subsequent treatment plans. Ever since the understanding of the dimensions of the nanotechnology, it has been suggested that it is the most important area of breakthrough considering its reverberation in the field of medical science. The most substantial contribution of nanotechnology to dentistry till date, is the more enhanced restoration of tooth structure with nanocomposites. The field of nanotechnology has tremendous potential, which if harnessed efficiently, can bring out significant benefits to the human society such as improved health, better use of natural resources, and reduced environmental pollution. The future holds in store an era of dentistry in which every procedure will be performed using equipments and devices based on nanotechnology. This article reviews the current status and the potential clinical applications of nanotechnology in dentistry.

KEYWORDS: Nanotechnology, Nanocomposites, Dental diagnosis.

INTRODUCTION:

Curiosity has its own reason for existing. For thousands of years, mankind has been harnessing its curiosity into inquiry and the process of scientific methodology. If we consider technology as an engine, then science is its fuel. Science of miniaturization (nanotechnology) is manipulating matter at nanometer level and the application of the same to medicine is called nanomedicine. “Nano” is derived from the Greek word which stands for “dwarf”. The label nano is given to particles varying in size from 1 to 1000 nm. Nanoparticles, owing to their small size, penetrate regions that may be inaccessible to other delivery systems, such as the periodontal pockets. A plethora of nanoparticulate systems have been attempted such as biodegradable polymeric nanoparticles, polymeric micelles, nanoparticles which are solid or lipid-based, organic or inorganic, dendrimers, magnetic nanoparticles, ferrofluids, and quantum dots, to name a few. As a family of nanoscale particulate materials, hydrogel nanoparticles (NPs) (currently referred to as nanogels), synergistically infusing the gel character at a nano level, have received much attention in recent times. The pharmacological world would consequently benefit from juxtaposition of a variety of properties like hydrophilicity, mechanical flexibility, versatility, and the indispensible biocompatibility of the nanoparticles.

HISTORY:

The term nanotechnology was coined by Prof. Kerie E. Drexler, a researcher and writer of nanotechnology. Humans have been using nanotechnology for a long time without realizing it. The processes of making steel, vulcanizing rubber and sharpening a dental instrument all rely on manipulations of nanoparticles. Richard Zsigmondy studied nanomaterials in the early 20th century, and later discoveries culminated in ideas presented by Nobel Prize winning physicist Richard Feynman in a lecture called “There's plenty of room at the bottom” in 1959, in which he explored the implications of matter manipulation.[1] Applications began in the 1980s with the invention of the scanning tunneling microscope and the discovery of carbon nanotubes and fullerenes.

The various nanostructures are (Freitas RA Jr, 1999)

1. Nanopores
2. Nanotubes
3. Quantum dots
4. Nanoshells
5. Dendrimers

NANODENTISTRY:

Nanodentistry will make possible the maintenance of near-perfect oral health through the use of nanomaterials, biotechnology including tissue engineering, and nanorobotics. Oral health and disease trends may change the focus on specific diagnostic and treatment modalities.

The fabrication techniques of these structures can be divided into 2 approaches: “bottom up” and “top- down”

Bottom-up approaches [2]

To arrange smaller components into more complex assemblies.

DNA Nanotechnology utilizes the specificity of Watson-Crick base pairing to construct well-defined structures out of DNA and other nucleic acids.

Top-down approaches[3]

To create smaller devices by using larger ones to direct their assembly

Nanodentistry as bottom-up approach:

Local anesthesia

In the era of nanodentistry, a colloidal suspension containing millions of active analgesic micron-size dental robots will be instilled on the patient's gingiva. After contacting the surface of crown or mucosa, the ambulating nanorobots reach the pulp via the gingival sulcus, lamina propria and dentinal tubules, guided by chemical gradient, temperature differentials, all under the control of dentist with the help of onboard nanocomputer. [Frietas RA, 2000]

Once instilled in the pulp, the analgesic dental robots may be commanded by the dentist to shut down all the sensitivity in any particular tooth that requires the treatment. After oral procedures are completed, the dentist orders the nanorobots on the computer screen to restore all sensation, to relinquish control of nerve traffic and to egress from the tooth by similar pathways used for ingress.

Hypersensitivity cure

Dentin hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive teeth have eight times higher surface density of dentinal tubules and tubules with diameters twice as large as non-sensitive teeth.

Dental nanorobots could selectively and precisely occlude selected tubules in minutes, using native biologic materials, offering patients a quick and permanent cure.

Tooth replacement

We are not far away when we will be able to generate whole new tooth with the principles of genetic engineering, tissue engineering and tissue regeneration, and manipulating cellular and mineral components at nanoscale.

Chen *et al*.[2005] by using nanorods like calcium hydroxyapatite crystals which were oriented roughly parallel to each other, were able to simulate the natural biomineralization process and create hardest tissue in human body, i.e., dental enamel.

Orthodontic treatment

Sliding a tooth along an archwire involves a frictional type of force that resists this movement. Use of excessive orthodontic force might cause loss of anchorage and root resorption.

In a study published by Katz, a reduction in friction has been reported by coating the orthodontic wire with inorganic fullerene-like tungsten disulfide nanoparticles (IF-WS_2), which are known for their excellent dry lubrication properties. In future, orthodontic nanorobots could directly manipulate the periodontal tissues, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours.

Photosensitizers and carriers

Quantum dots can be used as photosensitizers and carriers. They can bind to the antibody present on the surface of the target cell and when stimulated by UV light, they can give rise to reactive oxygen species and thus will be lethal to the target cell.

Diagnosis and treatment of oral cancer

Nano electromechanical system (NEMS) converts biochemical to electrical signal and cantilever array sensor is an ultrasensitive mass detection technology that can be used for the detection of 10–12 bacteria, viruses and DNA. These are extremely useful in the diagnosis of oral cancer and diabetes mellitus and for the detection of bacteria, fungi and viruses. Nanomaterials for brachytherapy like "BrachySilTM" (Sivida, Boston & Perth, Australia) deliver 32P, are in the clinical trial. Drug delivery system that can cross the blood brain barrier is vision of the future with this technology. Parkinson disease, Alzheimer disease, brain tumors will be managed more efficiently.

Nanorobotic dentifrice (Dentifrobots)

A subocclusal-dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day, metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement.[4]

Gene Therapy

Three main types of gene delivery systems have been described: viral vectors, nonviral vectors (in the form of particles such as nanoparticles, liposomes, or dendrimers), and the direct injection of genetic materials into tissues using so-called gene guns. Applications of nanotechnological tools in human gene therapy has been reviewed widely by Davis, who described nonviral vectors based on nanoparticles (usually 50-500 nm in size) that were already tested to transport plasmid DNA. He emphasized that nanotechnology in gene therapy would be applied to replace the currently used viral vectors by potentially less immunogenic nanosize gene carriers. So delivery of repaired genes or the replacements of incorrect genes are fields in which nanoscale objects could be introduced successfully.[5]

Nanodentistry as top-down approach

Nanocomposite

Nanoscientists have successfully manufactured non agglomerated discrete nanoparticles that are homogeneously distributed in resin or coating to produce nanocomposite (Feltech O Universal Restorative). These products have superior strength, hardness, esthetic appeal, excellent color density and high polish retention.

The nanofiller used includes an aluminosilicate powder having a mean particle size of 80 nm and a 1:4 M ratio of alumina to silica and a refractive index of 1.508.

Advantages

- Superior hardness
- Superior flexural strength, modulus of elasticity, and translucency
- 50% reduction in filling shrinkage
- Excellent handling properties
- Trade name: Filtek O Supreme Universal Restorative Pure Nano O.

Nanosolution

Nanosolutions produce unique and dispersible nanoparticles, which can be used in bonding agents. This ensures homogeneity and ensures that the adhesive is perfectly mixed everytime.

Trade name: Adper O Single Bond Plus Adhesive Single Bond.

Impression materials

Nanofillers are integrated in vinylpolysiloxanes, producing a unique addition of siloxane impression materials. The material has better flow, improved hydrophilic properties, and enhanced detail precision.

Trade name: Nanotech Elite H-D

Nanoencapsulation

Nanomaterials, including hollow spheres, core-shell structure, nanotubes and nanocomposite, have been widely explored for controlled drug release.

Pinon–Segundo *et al*.[2005] studied Triclosan-loaded nanoparticles, 500 nm in size, used in an attempt to obtain a novel drug delivery system adequate for the treatment of periodontal disease. These particles were found to significantly reduce inflammation at the experimental sites. An example of the development of this technology is arestin in which minocycline is incorporated into microspheres for drug delivery by local means to a periodontal pocket. [Paquette DW, 2004]

SWRI [South West Research Institute] has developed targeted release systems that encompass nanocapsules including novel vaccines, antibiotics, and drug delivery with reduced side effects.

At present, targeted delivery of genes and drugs to human liver has been developed by Osaka University in Japan [2003]. Engineered Hepatitis B virus envelope L particles were allowed to form hollow nanoparticles displaying a peptide that is indispensable for liver-specific entry by the virus in humans.

Future specialized nanoparticles could be engineered to target oral tissues, including cells derived from the periodontium [Yamadaet al, 2003]

Nanoneedle

Suture needles incorporating nano-sized stainless steel crystals have been developed.

Trade name: SandvikBioline, RK 91™ needles [AB Sandvik, Sweden].

Nanotweezers are also under development which will enable the dentist, to make cell-surgery possible in the near future.

Bone replacement materials

Nanophase hydroxyapatite

Osteoblastic adhesion and growth are vastly increased on nanophase hydroxyapatite (HA) than on traditional HA.

In addition, nanophase alumina and titania also show similar features. Hydroxy apatite nanoparticles used to treat bone defects are:

- Ostim HA (Osartis GmbH, Germany)
- Vitosso (Orthovita, Inc) HA + TCP (tricalcium phosphate)

Nanophase carbon

Carbon nano fibers have extra ordinary conjectural mechanical properties in addition to nanoscale dimensions like natural HA; these features support its proposals a maxillofacial implant material. (Webster TJ,2001)

Laser Plasma Application for periodontia

Application of nanosizedtitania particle emulsion on human skin followed by laser irradiation, leads to the disintegration of the particles along with other results like:

- Shock waves
- Microabrasion of hard tissues
- Stimulus to produce collagen (Freitas RA Jr. 2005)

Clinical applications:

1. Periodontal therapy
2. Melanin removal
3. Soft tissue incision (without anesthesia)
4. Cavity preparation- Enamel and dentin cutting

Prosthetic Implants

Nanotechnology would aid in the development of surfaces with definite topography and chemical composition leading to predictable tissue-integration. Tissue differentiation into definite lineage will accurately determine the nature of peri-implant tissues. In addition, antibiotics or growth factors may be incorporated as CaP coating is placed on Ti implants. (Le Gu´ehennec L 2007)

eg: Nanotite™ Nano-Coated Implant.

Nanoparticles and their Antimicrobial Activity with the Proposed Action

PARTICLE	ACTION
Silver	Silver Ag ions are responsible for disrupting membranes and repairing a damage in genetic structures
Zinc oxide	Responsible for disrupting cell membranes and initiation of H_2O_2 release
Ammonia	Causes disruption of cell wall by penetrating it
Gold	Has an effective electrostatic potential
Carbon`	Oxidizes the constituents of the membrane thus causing disruption

Current researches:

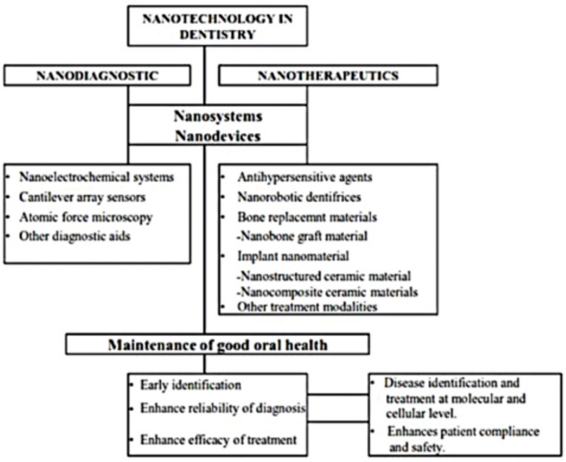
Liposomes:

Liposomes are small artificial vesicles of spherical shape that can be produced from natural nontoxic phospholipids and cholesterol. One of the most investigated approaches to gene therapy uses liposomes as submicron-scale delivery vehicles consisting of a lipid shell surrounding a core containing a therapeutic molecule or gene.

Nanoimplants:

The most frequent cause of failure of implants is insufficient bone formation around the biomaterial immediately after implantation. With coating of nanoparticles over the dental implants, adhesion and integration to surrounding tissues is improved. The nanostructured materials can exhibit enhanced mechanical, electrical, magnetic, optical properties compared with the conventional micron-scale or macro –scale counterparts.

To summarize:



Challenges faced by nanodentistry

Engineering challenges

- Feasibility of mass production technique
- Precise positioning and assembly of molecular scale part
- Manipulating and coordinating activities of large numbers of independent microscale robots simultaneously

Biological challenges

- Developing biofriendly nanomaterial
- Ensuring compatibility with all intricate of human body

Social challenges

- Ethics
- Public acceptance
- Regulation and human safety

CONCLUSION:

Nanotechnology will modify the dentistry, healthcare and human life more than any other developments of the past. Nanotechnology also holds promise for advanced diagnostics, targeted drug delivery making health care more effective and affordable. The application of nanotechnology in dental science is a novel proposition. The advantages of the nanotechnology would enhance the effectiveness of the already available technology. However, one cannot ignore the negative implications of the nanotechnology and hence the pros and cons of the technology must be considered before employment for commercial purposes. With time, nanotechnology has the potential to play a vital role in the both dental and medical fields.

REFERENCES:

1. Chandki R, Kala M, Kumar KN, Brigit B, Banthia P, Banthia R. 'Nanodentistry': Exploring the beauty of miniature. Journal of clinical and experimental dentistry. 2012 Apr;4(2):e119.
2. Herzog A. Of genomics, cyborgs and nanotechnology: a look into 8. the future of medicine. Conn Med. 2002;66:53-4.
3. Ashley S. Nanobot construction crews. Sci Am. 2001;285:84-5
4. Freitas RA Jr. Nanodentistry. Journal of American Dental Associa1. tion. 2000;131(11):1559-65.
5. Davis SS. Biomedical applications of nanotechnology—implications for drug targeting and gene therapy. Trends Biotechnol. 1997; 15(6):217-24
6. Nanotechnology and its role in the management of periodontaldiseases. Kong XL, Peng Z, LiS & Bartold PM. Periodontology 2000, Vol. 40, 2006, 184–196
7. Nanotechnology in dentistry: Present and future.Bhardwaj A, Abhinav Misuriya1,Maroli S.Journal of International Oral Health 2014; 6(1):121-126.
8. Nanotechnology and Dental Implants. Review. Sandrine Lavenus,1, 2 Guy Louarn,2 and Pierre Layrolle1. International Journal of BiomaterialsVolume 2010
9. Nanotechnology in dentistry. Vijalakshmi.Ind J Dent Res 17(2): 62-65, 2006.